

CHAPTER 4 RADIOACTIVE MATERIALS**TABLE OF CONTENTS**

<u>Article</u>	<u>Page</u>
PART 1 RADIOACTIVE MATERIAL IDENTIFICATION, STORAGE AND CONTROL	2
411 Definitions.....	2
412 Requirements.....	3
413 Radioactive Material Labeling and Handling	4
Table 4-1 General Labeling Requirements for Radioactive Materials.....	5
Table 4-2 Radioactivity Class Labels	5
414 Radioactive Material Packaging.....	7
415 Radioactive Material Storage	7
PART 2 RELEASE AND TRANSPORTATION OF RADIOACTIVE MATERIAL	10
421 Release to Controlled Areas	10
422 Release to Uncontrolled Areas	11
423 Transportation of Radioactive Material	11
PART 3 RADIOACTIVE SOURCE CONTROLS.....	15
431 Radioactive Source Controls	15
432 Procurement of Radioactive Sources at Fermilab.....	17
Table 4-3 Typical Sources in Inventory	18
433 Responsibilities of Persons Using Radioactive Sources at Fermilab	18
PART 4 RADIOACTIVE WASTE MANAGEMENT.....	20
441 Requirements.....	20
442 Waste Minimization	22
443 Mixed Waste.....	22
PART 5 CONTROL OF RADIOACTIVE LIQUIDS AND AIRBORNE.....	23
451 Minimization and Control of Radioactive Liquid Wastes	23
452 Control of Airborne Radioactivity	24
PART 6 SUPPORT ACTIVITIES.....	24
461 Personal Protective Equipment.....	24
462 Decontamination	25
463 Vacuum Cleaners and Portable Air-Handling Equipment.....	25

PART 1 RADIOACTIVE MATERIAL IDENTIFICATION, STORAGE AND CONTROL**411 Definitions**

Any material, equipment or system component which has been exposed to particle beams or rendered contaminated by contact with accelerator activated material or with naturally occurring radioactive material is considered suspect radioactive material. Furthermore, items located in known or suspected Contamination, High Contamination or Airborne Radioactivity Areas and having the potential to become contaminated are considered suspect radioactive material. Radioactive material includes sealed and unsealed sources. Controls for sealed sources are described in Part 3 of this Chapter. Appendix E of 10 CFR 835 defines quantities of radioactive materials that are considered "accountable" under 10 CFR 835.

Radioactive Material: Fermilab has established a practical release criterion for materials, equipment, and waste based on the use of field survey instruments. Materials, equipment, system components, waste items, or waste containers are considered to be radioactive if:

- On a contact survey the gross count rate with any surface is greater than twice the mean background count rate as measured in a low background (<2000 cpm) with a standard Bicron Analyst™ gamma scintillation probe.
- or
- On a contact survey the net count rate above mean background with any surface is greater than 2000 cpm as measured in a moderate background (≥ 2000 cpm but <3000 cpm) with a standard Bicron Analyst™ gamma scintillation probe.
- or
- On a contact survey the net count rate above mean background with any surface is greater than 50 cpm above mean background on an Eberline E140N or Ludlum 177-4 Frisker survey instrument.
- or
- The concentrations of any radionuclides contained within the material matrix equal or exceed those specified in applicable federal, DOE, state, or local regulations.
- or
- They have removable or fixed surface radioactivity which equals or exceeds the limits established in Table 2-2.

If any of these conditions are satisfied, then the material in question is radioactive by definition.

412 Requirements

1. Materials which have been in areas where activation is possible shall be considered radioactive material until surveyed. Materials in Contamination, High Contamination or Airborne Radioactivity Areas shall also be considered suspect radioactive material until surveyed, unless the area is an Airborne Radioactivity Area where only gaseous, short-lived (half-life of 1 hour or less) activation products are present (such as represented by the accelerator-produced airborne radionuclides — ^{11}C , ^{13}N , ^{15}O , and ^{41}Ar — at Fermilab). Surveys must assess the applicability of the criteria in Article 411, unless process knowledge is available. **Also see Articles 421.1 and 422.1.**
 - a. As materials are removed from beamline enclosures where activation is possible (as designated by cognizant members of the Radiological Control Organization), the items shall be surveyed and labeled appropriately.
 - b. Materials or system components which are processed in such a way as to remove all or part of the gamma emitting radionuclides they may contain are specifically exempt from the definition set forth in article 411. The specific activities of exclusive beta emitting radionuclides can no longer be accurately correlated with those of the gamma emitting radionuclides in such cases. Laboratory analysis must be used to ascertain the radioactive status if process knowledge is insufficient.
 - c. Known or suspected alpha emitters must be surveyed with an “alpha meter” obtainable from the ES&H Section. Materials known to be or suspected of being contaminated with low energy beta emitters (e.g., ^3H or ^{63}Ni) also require special survey techniques. In such cases, the ES&H Section should be contacted.
2. If an item is found to be radioactive and it is to remain on site, surveys should be performed promptly with a Ludlum 14C-1, Bicron Surveyor (for Classes 1 and 2), or Wallflower Geiger survey meter, to determine which Class label should be applied and filled out completely.
3. Any material, equipment, system component, waste item, or waste container with removable contamination levels equaling or exceeding the levels specified in Table 2-2 are considered radioactively contaminated. If they can be decontaminated to levels below those specified in Table 2-2 and are not otherwise radioactive then they may be reclassified as non-radioactive material.
4. Material determined to be nonradioactive may be disposed of as waste or taken off site without restriction as to its radioactivity. All radioactive labels should be removed from the material when it is determined not to be radioactive (see Article 413.10).

Disposal of radioactive or suspect objects as surplus or scrap requires the approval of the ES&H Section Head or designee. Arrangements will then be made for such disposal in accord with DOE, Federal and State requirements (see Part 4 of this Chapter).

5. A system or piece of equipment should be broken down into the smallest number of components that is practical and the radioactivity of each item determined individually. This helps ensure that the amount of radioactive waste generated is minimized.
6. If a group of individual items, which by themselves would not be classified as radioactive, are placed together in aggregate in such a manner that the aggregate meets the definition of a radioactive material found in Article 411, then the aggregate must be considered radioactive.
7. In cases where materials are brought on site containing naturally occurring radioactive material (NORM) such as thoriated tungsten welding rods or blasting grit, the background to be used in determining the radioactive status of residues should be the radiation field produced by a non-activated or contaminated sample in the same counting geometry as the sample being analyzed. In most cases, this background will be significantly higher than the ambient background.

413 Radioactive Material Labeling and Handling

1. Fermilab has implemented a system of labeling radioactive materials outside beam enclosures which assigns classes to them based upon the exposure rates. In addition, Table 4-1 lists general labeling requirements for radioactive materials. All radioactive material outside radiological areas shall be labeled in accordance with Tables 4-1 and 4-2.

Table 4-1 General Labeling Requirements for Radioactive Materials

	REQUIRED LABELING
Equipment, components and other items that are radioactive	“CAUTION, RADIOACTIVE MATERIAL” (but use Table 4-2 for radioactive label classes)
Sealed and unsealed radioactive sources or associated storage containers	“CAUTION, RADIOACTIVE MATERIAL” or standard radiation symbol
Equipment, components and other items with actual or potential internal contamination	“CAUTION, CONTAMINATED MATERIALS” or “CAUTION, POTENTIAL INTERNAL CONTAMINATION HAZARD”
Components, equipment or other items with fixed contamination (see Article 221)	“CAUTION, FIXED CONTAMINATION”

Table 4-2 Radioactivity Class Labels

Label	Exposure Rate (mR/hr @ 1 ft)	
	At Least	but Less Than
CAUTION RADIOACTIVE MATERIAL Class 1	Satisfies definition in Article 411	1 mR/hr
CAUTION RADIOACTIVE MATERIAL Class 2	1	10 mR/hr
CAUTION RADIOACTIVE MATERIAL Class 3	10	100 mR/hr
DANGER RADIOACTIVE MATERIAL Class 4	100	1000 mR/hr (= 1 R/hr)
DANGER: HIGHLY RADIOACTIVE MATERIAL Class 5	1 R/hr	----

2. Radioactive material may be capable of generating a Radiation Area, High Radiation Area, or Very High Radiation Area. These areas shall have special controls in accordance with Article 333 and be posted/designated in accordance with Article 234.
3. The Laboratory has developed response and notification requirements associated with a loss of radioactive material, including searches, internal investigations, documentation and reporting. The Radiological Control Organization is to be

Radioactive Materials**Chapter 4**

- notified in the event of a loss or theft of radioactive material. This includes radioactive sources.
4. The following are not subject to item labeling requirements as set forth in Table 4-1:
 - a. Radioactive material located in areas posted in accordance with the requirements of Articles 234-236.
 - b. Radioactive material or containers packaged and labeled for off site shipment in accordance with Department of Transportation Regulations.
 - c. Equipment or installed system components undergoing maintenance covered by a Radiological Work Permit.
 - d. Installed system components located within an area, inaccessible to individuals.
 - e. Items located within areas posted in accordance Article 233 when it is impractical to label all items. Such items shall be properly surveyed and labeled when they are removed from such areas.
 - f. Short-lived (half-life of 1 hour or less) radioactive material generated during an irradiation (i.e., research samples while an experiment is being conducted, etc.) that is immediately used.
 5. The following are not subject to labeling requirements if they are Class 2 or less and if they are not significantly ($\geq 10X$ general background) more radioactive than ambient radiation fields where they are stored:
 - a. Radiological control samples such as air, process and soil samples or swipes that are in the custody of personnel properly trained in the handling, packaging and transport of these samples.
 - b. Portable tools and equipment with fixed contamination permanently marked with yellow or magenta and maintained in a labeled contaminated tool crib or storage and distribution area.
 - c. Personal Protective Equipment and clothing.
 6. Labels shall have a yellow background with a magenta or black standard radiation warning trefoil. Lettering shall be magenta or black.

Radioactive Materials**Chapter 4**

7. Labels should include contact radiation levels or dose at 30 cm (1 foot) (see Tables 4-1 and 4-2), removable surface contamination levels, if any (specified as alpha or beta-gamma), dates surveyed, and surveyor's initials.
8. Packaged radioactive material should have the label visible through the package or affixed to the outside.
9. When certain radionuclides (some alpha sources, tritium, etc.) are packaged so that no radiation is detectable outside the container, a Caution, Radioactive Material label shall be used. Additional information, such as the radionuclide present, specific activity, etc., shall be affixed to the container.
10. Non-radioactive materials should not carry radioactivity Class labels. Good practice is to check items whenever practical, reclassify items which need a new label, and remove all labels if the item is no longer radioactive.
11. Hand tools and equipment stored in radiation areas may be marked with magenta paint to denote that they are radioactive. Outside these areas they must be marked with the appropriate radioactivity Class labels.

414 Radioactive Material Packaging

1. Material that is outside Contamination, High Contamination or Airborne Radioactivity Areas and is confirmed or suspected of having removable radioactive contamination levels greater than Table 2-2 values shall be securely wrapped in plastic or placed in a container, such that any potential contamination from that material will be completely contained.
2. Contaminated material with sharp edges or projections should be taped or additionally protected to ensure package integrity.
3. Contaminated material with removable contamination levels in excess of 100 times Table 2-2 values should have additional packaging controls such as double-wrapping or the use of plastic bags inside containers.
4. Yellow plastic wrapping material should be used in packaging radioactive material for storage, transportation, or shipment. Yellow plastic sheets or bags should not be used for nonradiological purposes.
5. The amount of combustible material used in packaging should be minimized and selected in accord with Fermilab ES&H Manual fire protection policies.

415 Radioactive Material Storage

Radioactive Materials**Chapter 4**

1. Areas where radioactive material is stored should be appropriately posted as set forth in Part 3 of Chapter 2.
2. Long-term (more than 1 year) storage of radioactive material should be in areas specifically designated for the storage of radioactive material. Portions of the Railhead currently constitute the Laboratory's major long-term storage area (see Subpart 12 below).

Radioactive materials shall not be stored off site (including buildings rented or leased by the Laboratory) or at certain specified on-site locations including the following:

- a. On site housing (dorms, etc.)
 - b. Established eating and drinking areas (lunch rooms, vending areas, etc.).
3. Decontamination or disposal of radioactive material is the preferred alternative to long-term storage except for equipment of significant value. For purposes of this Article, "value" may be either defined in terms of financial considerations or in terms of the difficulty of replacing the materials or equipment in question.
 4. Each area where radioactive material is stored should be approved by the division/section RSO.
 5. A custodian should be assigned responsibility for each area where radioactive material is stored. A custodian may have responsibility for more than one storage area.
 6. The custodian should conduct periodic walkthroughs of areas where radioactive material is stored or used to check for adherence to Laboratory policies, especially with respect to the minimization of material accumulation, proper labeling, and container integrity.
 7. Storage of nonradioactive material in any radiological area should be minimized in so far as is practical.
 8. Outdoor storage of radioactive material is discouraged. Any new outdoor storage locations shall be approved by the Laboratory Director. In cases where outdoor storage is necessary and where removable radioactivity is present, the integrity of containers used shall be ensured to prevent degradation from weathering and subsequent release of radioactive material. The custodian should check container integrity annually, or more frequently if conditions require it at outdoor storage areas.

Radioactive Materials**Chapter 4**

9. Radioactive material should be stored in a manner that reduces combustible loading. The use of cardboard containers for storage is discouraged.
10. Flammable or combustible materials should not be stored adjacent to areas where radioactive material is stored or used.
11. Fire protection measures, such as smoke detectors, water sprinklers and fire extinguishers, should be considered when establishing areas for the storage and usage of radioactive materials.
12. Specific locations in the Railhead area of the Laboratory are designated for general storage of radioactive material. Limited indoor storage, built from shielding blocks, is available in Lundy Barn. However, the building is not heated, air conditioned or completely waterproof, so some environmental effects should be expected. The procedures for using this storage area are given below.

- a. General

- (1) Storage of radioactive material at the Railhead facilities is under the direct control of Business Services Section Support Services Department. Arrangements for storage may be made by calling them.
- (2) All portable items (items weighing less than 200 lbs.) must be stored in a secure area, e.g., either inside a building or in a fenced and locked area outside. If stored outside, provision should be made to prevent any environmental contamination or theft.
- (3) All items must be surveyed, labeled with the exposure rate, date of survey, and contamination level, if any. It is the responsibility of the division or section requesting the storage to arrange for appropriate radiation surveys.

- b. Limits

- (1) Exposure Rate Limits

Any class 4 or higher item shall be stored with enough shielding to reduce the radiation level outside the shield to below 100 mR/hr.

- (2) Contamination Limits

- (i) When practical, all surfaces of all items shall be decontaminated to levels less than those specified in Table 2-2.

- (ii) Items which cannot be decontaminated must be covered with a waterproof barrier (e.g. herculite) and put inside a container which will provide weather protection for the duration of storage. Class 4 and 5 radioactive items which are subject to corrosion shall be covered with a waterproof barrier. Other unusual situations such as those which may involve radioactive liquid, powder, etc., will be handled on a case-by-case basis.

PART 2 RELEASE AND TRANSPORTATION OF RADIOACTIVE MATERIAL

421 Release to Controlled Areas

1. Materials released from radiological areas to Controlled Areas should be promptly categorized as radioactive or non-radioactive based on the definition found in Article 411 or the process knowledge of the individuals releasing the material.
2. A wipe survey shall be performed on radioactive material in Contamination, High Contamination or Airborne Radioactivity Areas unless a frisk survey can demonstrate that the removable contamination levels are below those specified in Table 2-2 and no alpha or low-energy beta emitting radionuclides are present. Unpackaged radioactive material to be released to Controlled Areas shall be demonstrated to have removable contamination levels less than Table 2-2 values.
3. Materials may be released for use in controlled areas provided that measurements of accessible surfaces show that removable contamination levels are below those in Table 2-2 and contamination levels on inaccessible surfaces are unlikely to exceed those levels. These items shall be routinely monitored and controlled in accordance with administrative procedures found in Article 221. Controls shall be established to ensure that no unmonitored individual is likely to exceed a dose equivalent that would require monitoring in accordance with Articles 511 or 521.
4. Radioactive material with removable contamination levels greater than Table 2-2 values which cannot be decontaminated shall be packaged prior to release to Controlled Areas. These items shall be routinely monitored and controlled in accordance with administrative procedures. Controls shall be established to ensure no unmonitored individual is likely to exceed a dose equivalent that would require monitoring in accordance with Articles 511 or 521.
5. Material not immediately removed from Contamination, High Contamination, or Airborne Radioactivity Areas after survey shall be controlled to prevent contamination while awaiting release. Potentially activated material not

Radioactive Materials**Chapter 4**

- immediately released after survey shall be controlled to prevent activation while awaiting release.
6. Records for release of potentially contaminated materials shall describe the property, date of last survey, identify of the person who performed the survey, type and identification number of the survey instruments used, and survey results.
 7. Radioactive material, equipment, or items released from radiological areas to Controlled Areas which are to be declared as waste shall be characterized as to the prominent radionuclide concentrations extant in the material. This should be done before its release, if possible; otherwise as soon as practical after its release.
 8. Materials released to Controlled Areas shall be labeled in accordance with Article 413.

422 Release to Uncontrolled Areas

1. Material in Controlled Areas or Radioactive Material Areas shall be categorized as radioactive or non-radioactive based on the definition found in Article 411.1 or the process knowledge of the individuals releasing the material prior to release to uncontrolled areas. (Note that special precautions apply to the use of radioactive materials in Wilson Hall as specified in Chapter 9.)
2. Fermilab removable surface activity criteria for releasing radioactive material to uncontrolled areas are consistent with regulatory requirements. Radioactive material being released shall also be evaluated for contamination under any coatings if "fixed" contamination is present. Such materials must have removable contamination levels less than those of Table 2-2 and no fixed contamination for such release to be permitted.
3. Material not immediately released after survey shall be controlled to prevent activation or contamination while awaiting release.
4. Labels shall be removed or defaced prior to release of materials, that are found to be no longer radioactive, for unrestricted use. Such labels shall be disposed of as radioactive waste.

423 Transportation of Radioactive Material

1. General Requirements for shipments
 - a. Table 2-2 removable contamination values shall be used as controlling limits for on site transportation when using a DOE conveyance (i.e., government vehicle). When a radioactive material shipment is received

Radioactive Materials**Chapter 4**

from or shipped to an off site destination, the requirements of 49 CFR173 Part I shall apply.

The DOT removable contamination limits stated in 49 CFR 173.443, as applied to Fermilab, are as follows:

Beta-gamma emitting radionuclides & U and Th:	2200 dpm/100 cm ² (1 nCi/100 cm ²)
Alpha emitters (except U and Th):	220 dpm/100 cm ² (0.1 nCi/100 cm ²)

- b. 49 CFR 171 through 180 describe requirements for inspecting and surveying packages, containers and transport conveyances prior to off site transport.
 - c. Transport conveyances should be visually inspected prior to loading to ensure the trailers are acceptable for the intended use.
 - d. Drivers of motor vehicles in which radioactive material is transported shall have a copy of all documentation required by applicable rules and regulations.
2. Shipment of Radioactive Material
- a. All material to be shipped off site which has been in beamline areas or is otherwise suspected of being radioactive must be categorized as either radioactive or non-radioactive based upon the definition in Article 411 or upon process knowledge:
 - (1) If a survey is required to determine if the item is radioactive, it shall be made by an appropriately trained individual. A copy of the Authorized Surveyor list can be obtained from the ES&H Section.
 - (2) Items which are not radioactive (see Article 411), provided they are free of labels or other indications that the item may have once been designated as radioactive, may be shipped without restrictions as to its radioactive content. This includes shipments going through the Receiving Warehouse Site 38 or delivery directly to a vendor's vehicle at the site location. A Material Move request must still be completed and signed attesting to the non-radioactive classification of the material.
 - b. All off site shipments of radioactive material shall be coordinated through the ES&H Section. Upon contact, the ES&H Section will provide information on the applicable packaging, marking and shipping regulations. The ES&H Section then makes the proper shipping or inspection

Radioactive Materials**Chapter 4**

arrangements through the Business Services Section. A Material Move request must accompany all off site shipments of radioactive material.

- c. Off site shipments of radioactive material, including subcontractors' handling of off site shipments, shall be controlled and conducted in accordance with this Manual and applicable Federal, state and local regulations.
 - d. Before shipment, a visual inspection of packages shall be performed to ensure that packages are not damaged. The inspection should identify dents, flaking paint, debris, package orientation and any indication of leakage.
 - e. Before shipment, a comparison of package count to the shipping manifest shall be made to ensure accountability.
 - f. Transport conveyances should be radiologically surveyed before loading a vehicle consigned as exclusive use or when using a commercial carrier specializing in radioactive material transport.
 - g. Transport of large volumes of radioactive material by non-DOE motor vehicles should be "exclusive use" to prevent commingling of DOE and other commercial shipments.
3. Receipt of Radioactive Material
- a. Receipt of radioactive material shall be arranged through and approved by the ES&H Section. If packages containing quantities of radioactive material in excess of a Type A quantity as defined in 10CFR71.4 are expected, arrangements shall be made to either:
 - (1) Take possession of the package when the carrier offers it for delivery; or
 - (2) Receive notification of its arrival at the carrier's terminal and to take possession of the package as soon as possible thereafter.
 - b. Upon receipt of a radioactive material shipment, a visual inspection of packages shall be performed to ensure that packages are not compromised. In addition, a comparison of the package count to the shipping manifest shall be made to ensure accountability.
 - c. External surfaces of packages known to contain radioactive material shall be monitored for both radiation and contamination levels if:

- (1) A Radioactive White I, Yellow II, or Yellow III label (as specified at 49CFR172.403 and 172.436-440) is present; or
 - (2) Has been transported as low specific activity material (as defined at 10CFR71.4) on an exclusive use vehicle (as defined at 10CFR71.4); or
 - (3) Has evidence of degradation, such as packages that are crushed, wet, or damaged.
 - d. Monitoring shall be completed as soon as practicable following the receipt of the package, but not later than 8 hours after the beginning of the working day following the receipt. Until the monitoring can be performed, the packages should be segregated and temporarily placed in a posted Radioactive Material Area. Exceptions are noted below:
 - (1) No measurements of removable contamination need be made when the package contains only special form (as defined in 10CFR71.4) or gaseous radioactive material; or
 - (2) No measurements of radiation levels are required when the package contains less than a Type A quantity (as defined in 10CFR71.4) of radioactive material.
4. Requirements for On Site Transfers
- The division or section heads are responsible for providing safe and environmentally responsible on site transfer of radioactive materials during work conducted by their personnel. The responsibility for proper transfer and transport shall, at a minimum, address the following:
- a. Providing appropriate labels which specify Class of radioactivity according to the provisions of this Chapter.
 - b. Meeting radiation safety handling, packaging, and shipping requirements. This may require special instructions from or supervision by radiation safety personnel.
 - c. Ascertaining that destinations are appropriate for receiving the material.
 - d. Arranging appropriate transportation. Such transfers are restricted to government vehicles with the exception of sealed check sources on field instruments maintained by the ES&H Section.

Radioactive Materials**Chapter 4**

- e. The vehicle should be driven directly to its destination with no unnecessary stops along the way. No "side trips" off site are allowed. No "side trips" to facilities frequented by the public on site are allowed (e.g., the recreation facilities, village residential units, and/or Wilson Hall unless the latter is the destination).
- f. Radioactive materials are not permitted in on site housing (e.g., dorms) or in established eating and drinking areas (e.g., lunchrooms and vending areas).
- g. Special restrictions apply to the radioactive materials in Wilson Hall (see Chapter 9 Part 1).
- h. The Fermilab Emergency Response Plan describes appropriate responses for potential on site radioactive material transportation accidents.

PART 3 RADIOACTIVE SOURCE CONTROLS**431 Radioactive Source Controls**

At a minimum, Fermilab's Source Control and Accountability Program will address sources meeting the criterion in Appendix E of 10CFR835, but has been expanded to include most, if not all, sealed sources on the site.

- 1. The design and construction details of all sources used at Fermilab must be reviewed and approved by the ES&H Section prior to construction, alteration, installation, or purchase as applicable.
- 2. The ES&H Section shall maintain, or cause to be maintained, accountability records for sealed sources.
- 3. The ES&H source physicist shall be appointed by the SRSO to maintain radioactive source controls. At Fermilab, procedures for radioactive source control and accountability are documented in the Source Control and Accountability Program.
- 4. Source users shall notify the ES&H Section of changes in use, storage, transfer, disposal, return or loss of a sealed source.
- 5. Except for sealed sources consisting solely of gaseous radioactive material or tritium, each accountable sealed source shall be leak tested under the following conditions and frequency:
 - a. Upon receipt.

Radioactive Materials**Chapter 4**

- b. Sources loaned by the ES&H Section are leak-tested (wiped) monthly, except for sources located in areas that are unsafe for human entry or otherwise inaccessible (e.g. sources installed in detectors).
 - c. Sources in the inventory of the ES&H Section are leak-tested (wiped) every 6 months, unless they have been removed from service or placed into storage. The time interval to conduct the leak tests may be extended by a period not to exceed 30 days to accommodate scheduling needs. Sources removed from service or placed in storage, including sources mounted on instruments, are not subject to periodic leak testing. Such sources shall be stored in a controlled location and shall be leak tested prior to being returned to service.
 - d. Whenever damage is suspected. Sources found to be leaking shall be controlled in a manner that minimizes the spread of contamination and removed from service.
 - e. Source leak tests shall be capable of detecting radioactive material leakage equal to or exceeding 0.005 microcurie.
- 6. Labels used to identify sealed sources shall also identify the radionuclide, date of assay, and source inventory number. The current list of source users is maintained in a database which associates them with the sources by inventory number.
 - 7. Procurement of radioactive sources shall be coordinated with the ES&H Section (see Article 432).
 - 8. Receipt surveys of source shipments shall be performed by the ES&H Section. These sources shall be leak-tested (see above) within 30 days of receipt.
 - 9. Sources, including radiography sources (see Article 362) shall not be brought on site without the prior approval of the SRSO or designee.
 - 10. Source monitors are designated for each source box/cabinet. Source monitors are responsible for the control of the source lock key issued to them by the ES&H Section, locking and unlocking source boxes, logging sources in and out on the source access log sheet and verifying source training of the user requesting the source.
 - 11. Source lock keys shall not be duplicated or transferred to another person.
 - 12. When a person is no longer designated a source monitor, he/she shall return the key to the ES&H Section.

Radioactive Materials**Chapter 4**

13. Source monitors shall notify the ES&H Section source physicist (or designee) if a source lock key is discovered missing, lost or found.

432 Procurement of Radioactive Sources at Fermilab

The ES&H Section maintains an inventory of frequently used sources which are available for loan to Fermilab employees and visiting experimenters. These sources are safely packaged and are available in different geometries to meet a variety of needs. Sources can be packaged in special holders to meet specific needs. A listing of the types of sources available is given in Table 4-3.

Special sources, or sources not available in inventory, can be procured through arrangement with the Radiation Physics Group for loan to individuals requesting them. The procedures for procurements are as follows.

1. After discussion of requirements, the purchase requisition must be routed through the ES&H Section and must be approved (signed) both by the division/section head (or designee) who supervises the work being done and by the SRSO.
2. A source loan form, R.P. Form #12, signed by the individual and, under certain conditions, division/section head (or designee) will then be required before the source may be issued. The responsibilities of persons using radioactive sources at Fermilab are listed on the back of this form as well as in Article 433.
3. Both Radioactive Source training (course #FN000048) and Radiation Worker training shall be provided to the employee or experimenter prior to source use. Training is documented on the Training Record and Information Network.
4. Shipment of sources from other institutions shall be first discussed with the ES&H Section. Sources purchased from outside vendors or shipped to Fermilab from other institutions are shipped directly to the ES&H Section through the Fermilab Receiving Department (Business Services Section).
5. The purchase requisition must include the following specifications pertinent to the shipment of radioactive sources to Fermilab.
 - a. Removable activity must be less than one nanocurie.
 - b. The Purchase Order should be marked "Prime DOE Contractor. No License Required."
 - c. The outside of the package must be marked "Contains radioactive material. Do not open at receiving. Contact Radiation Physics on arrival."

Table 4-3 Typical Sources in Inventory

Nuclide	Half-life	Principal Radiations	γ Energy, or Maximum β Energy, MeV	Range of Activities
^{55}Fe	2.7 yr.	γ	0.006 (Mn X-ray)	0.07 μCi to 10 mCi
^{60}Co	5.27 yr.	γ	1.17, 1.33	0.003 μCi to 2 mCi
^{137}Cs	30.2 yr.	γ	0.662	0.03 μCi to 2 mCi
^{22}Na	2.60 yr.	γ	0.511, 1.27	0.006 μCi to 2 mCi
^{90}Sr	29 yr.	β^- , no γ	0.546 β , 2.27 β (from daughter ^{90}Y)	0.03 μCi to 5 mCi
^{106}Ru	368 days	β^- , γ	3.54 β (from daughter ^{106}Rh)	0.01 μCi to 100 mCi
^{207}Bi	38 yr.	γ , Internal Conversion Electron	0.570, 1.0648 γ ; 0.976, 0.482 ICE	0.03 μCi to 2 μCi
^{241}Am	432 yr.	α , γ	5.48 α ; 0.026, 0.060 γ ; numerous Np X-rays	0.1 μCi to 10 mCi

433 Responsibilities of Persons Using Radioactive Sources at Fermilab

1. The user shall not tamper with, disassemble or modify a source or its holder in any way, nor remove any source from its holder or housing. Requests for source installation or new or modified source holders or housing must be discussed with ES&H Section personnel.
2. If a user purchases a radioactive source, purchase requisitions must be routed through the ES&H Section source physicist (or designee) for proper approval and signatures.
3. Radioactive sources shall not be brought to or taken from Fermilab unless approved in advance by Fermilab's Senior Radiation Safety Officer (SRSO) or designee.
4. Radioactive sources shall be kept in a locked box/cabinet when not in use. The storage box/cabinet shall bear sign(s) "Caution Radioactive Material." Tool boxes and other portable containers are not acceptable source storage containers.
5. Sources and source boxes/cabinets shall be accessible to ES&H Section personnel for monthly inventory and leak testing.

Radioactive Materials**Chapter 4**

6. Personnel dosimetry monitoring badges shall be worn and a "Caution Radiation Area" sign shall be displayed when the potential exists for an individual to receive a dose of ≥ 5 mR in 1 hour at a distance of 30 cm (1 foot) from the source.
7. A "Caution Radioactive Material" sign shall be displayed near the source during use. If a source is contained within detection equipment, a "Caution Radioactive Material" label with the source I.D. clearly stated must be attached to the outside of the equipment.
8. The user shall not leave sources unattended unless special arrangements have been made through the ES&H source physicist to ensure adequate source control.
9. The ES&H source physicist shall be notified if a source needs to be in use for an extended period of time without returning it to its storage box/cabinet. Special arrangements shall be made to ensure adequate source control.
10. The user shall not detach the "Caution Radioactive Material" tag/label or the source I.D. label from the source.
11. ES&H Section source physicist shall be contacted to arrange for source transfers. Under most circumstances, ES&H Section personnel will transport the source to the new location. Likewise, when a source is issued, ES&H Section personnel will deliver the source to the storage location designated on the source loan form. The user shall not transport sources in private vehicles. After consultation with the ES&H Section source physicist or designee, division/section personnel may transport sources on site in government vehicles provided that the source is returned to its assigned storage location at the end of the workday.
12. The user shall notify the ES&H Section source physicist (or designee) when the source is no longer needed. ES&H Section personnel will pick up the source and return it to ES&H Section storage.
13. The user shall promptly notify the ES&H Section source physicist (or designee) if a source is discovered missing, lost or found.
14. If a user suspects that a source is broken or causing contamination, the user shall call or have someone call x3131 immediately. Source should not be removed from its storage location or current location if in use. Others should be kept away from the source.
15. The user shall contact the ES&H Section source physicist (or designee) to obtain a source that is not currently located in a source storage box. The ES&H Section source physicist (or designee) shall complete the radioactive source loan form (R.P. Form #12) and the user shall sign and date the form.

16. Exceptions to any of the above rules shall be approved in advance in writing by the SRSO. Departures from these rules may result in confiscation of the source(s). Severe or repeated violations may result in loss of privilege to use radioactive sources at Fermilab.

PART 4 RADIOACTIVE WASTE MANAGEMENT

441 Requirements

All radioactive material which is not needed for present or probable future use should be disposed of as radioactive waste. In addition, any signs, tags, or labels used to indicate the presence of radiation and/or radioactive material must be destroyed beyond recognition or disposed of as radioactive waste. Compactible radioactive waste such as disposable protective clothing, rags, and compressible items shall be placed in yellow radioactive waste bags. Normally, non-compactible solid and liquid radioactive waste must be placed in approved containers provided by the ES&H Section. Large items which are suitable for "contact burial" may be disposed of without containment. Where applicable, these items are to be placed on pallets, or in the case of pipe, banded in bundles. Compactible and non-compactible waste must be kept separate to allow maximum efficiency in the radioactive waste disposal program.

Specific procedures for disposal of radioactive waste can be found in the Low-Level Waste Certification Plan (LLWCP) and division/section waste procedures. Radiological operations generating radioactive waste should be designed and developed to permit segregation, monitoring, storage and disposal. The ES&H Section should be contacted if questions or problems arise.

1. Procurement, Delivery, and Storage of Radioactive Waste Containers
 - a. The ES&H Section, is responsible for ordering, inspecting, and issuing radioactive waste containers. The containers available are:
 - (1) Yellow 55 gal. steel drums, UN1A2. The loaded weight shall not exceed 948 lbs (430 kg)
 - (2) 8 mil. yellow poly bags
 - (3) 4' X 3.5' X 4' steel boxes. These boxes are intended for approved contact burial items only, and must contain no glass, dirt, sand, sweeping compound, or wet material. They hold up to 50 ft³ of items and must not exceed 3000 lbs. gross weight.

Radioactive Materials**Chapter 4**

- b. Delivery of empty containers to individual areas on non-pickup days should be coordinated through the ES&H Section. Recipients should place drums indoors, where practical, within 24 hours after delivery. In any case, lids must remain on drums.
- 2. Location and Use of Waste Containers
 - a. Drums must remain indoors or in an area protected from the weather while in use. Boxes may be used outdoors at locations designated by area supervisors or radiation safety personnel.
 - b. "Portable" radioactive waste items weighing less than 200 lbs. must be placed in approved waste containers or kept in a secure area, e.g., either inside a building or in a fenced and locked area outside.
- 3. Radioactive Waste Packaging Requirements
 - a. Solid Non-compactible Waste and Liquid Waste

55 gal. radioactive waste drums and steel boxes are the only approved containers for solid radioactive waste. Special 30 gal. liquid waste drums must be used for most liquid radioactive wastes. Small volume liquid waste streams will be handled on a case-by-case basis. Contact the ES&H Section for packaging instructions. Radioactive waste identification labels will be affixed to containers by the ES&H Section prior to delivery to specific areas. When containers are full, lids must be secured on them.

If items are too large for containers, the ES&H Section should be contacted to determine what method of disposal should be used.
 - b. Compactible Waste

All compactible waste must be put into large yellow polyethylene bags that are designated for this purpose. The bags must not contain the following:

 - Metal or wood
 - Glass in any form
 - Cable over 12" long
 - Dirt, sand, sweeping compound or wet material
 - c. Specific procedures for waste generators, and other waste packaging requirements are documented in the Fermilab Low-Level Waste Certification Plan (LLWCP) which is maintained by the ES&H Section.

4. Radioactive Waste Pickup

Radioactive waste pickups are performed periodically. Waste generators should request that waste be picked up by submitting a completed "Radioactive Waste Certification and Pickup Request Form" to their division/section radioactive waste coordinator. The same form may be used to request empty container delivery.

442 Waste Minimization

A radioactive waste minimization program is in effect to reduce the generation of radioactive waste and spread of contamination from Contamination, High Contamination or Airborne Radioactivity Areas. This plan is a part of the Laboratory's general waste minimization plan which is stated in Fermilab ES&H Manual Chapter 8022. The following practices should be instituted to support minimization of radioactive wastes:

1. Limit the quantities of material entering beamline enclosures or radiological areas to those needed for performance of work.
2. Restrict quantities of hazardous materials, such as paints, solvents, chemicals, cleaners and fuels, entering beamline enclosures and other radiological areas and take measures to prevent inadvertent radioactive contamination of these materials.
3. Use recyclable items and reuse equipment when practical and consistent with other measures necessary to protect worker safety and health and the environment and with other articles of this manual.
4. Reserve an assortment of tools primarily for use in Contamination, High Contamination or Airborne Radioactivity Areas as appropriate.
5. Segregate known unactivated and/or uncontaminated from potentially activated and/or contaminated waste.
6. Segregate reusable items, such as respirators and tools.
7. Optimize the number and size of areas where radioactive material is stored or used.
8. Emphasize training in waste reduction philosophies, techniques and improved methods.

443 Mixed Waste

Radioactive Materials**Chapter 4**

Requirements specified in the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA) apply to waste that contains both radioactive and hazardous materials. Certain features of the recipient state regulations also apply to these wastes and are stated in the LLWCP and in Fermilab's RCRA Part B Permit (issued to cover the operations of the Site 55 Hazardous Waste Storage Facility).

1. Article 442 describes how mixed waste generation should be minimized.
2. Technical and administrative controls should be established to minimize the volume of mixed waste generated and the amount of radioactivity in such waste. Volume reduction methods include process optimization, materials substitution and new technology development.
3. Materials suspected of being mixed waste should be identified and segregated as soon as practical in the generating process to avoid combining mixed waste with other waste.
4. Materials identified as being mixed waste must be characterized as to their hazardous and radioactive material content in accordance with all applicable regulations.

PART 5 CONTROL OF RADIOACTIVE LIQUIDS AND AIRBORNE

451 Minimization and Control of Radioactive Liquid Wastes

1. A water management program is in place (see Article 347) to identify, trend and eliminate unnecessary sources of radioactive liquid waste. This program should include measures to identify and repair leaks.
2. Activities that produce radioactive liquid waste shall be suspended unless sufficient processing, collection and storage capacity is available to accommodate the waste.
3. Radioactive liquid waste discharge requirements are addressed elsewhere in this manual.
4. Radioactive liquid waste discharges should be characterized and releases terminated before exceeding predetermined limits. Discharges of radioactivated water is described elsewhere in this manual.
5. Radioactive liquid waste that cannot be discharged shall be solidified and disposed of as solid radioactive waste.

452 Control of Airborne Radioactivity

1. Processes and activities with the potential for producing significant airborne radioactivity shall include engineering controls to limit releases or properly monitor them. Controls pertinent to beamline operations are covered in more detail in Chapters 10 and 11.
2. The RSO shall be notified when engineering controls that prevent exposure of individuals to airborne radioactivity, such as barriers, gloveboxes and glovebags, are compromised. An evaluation should be made of continuing operations with compromised engineering controls. The use of respiratory protection to continue is discouraged. Implementation of short-term engineering modifications that provide a commensurate level of protection of individuals is the preferred alternative.
3. Preventive maintenance and surveillance procedures should be established to ensure equipment controls are maintained in an operable condition for containment of airborne radioactivity.
4. Procedures for evaluation and monitoring of airborne radioactivity at Fermilab can be found in the Fermilab ES&H Section publication Airborne Radionuclide Emissions Monitoring Program Procedures Manual.

PART 6 SUPPORT ACTIVITIES**461 Personal Protective Equipment**

1. Protective clothing designated for radiological control use should be specifically identified by color, symbol or appropriate labeling.
2. Protective clothing used for radiological control use shall not be used for nonradiological work.
3. Personal Protective Equipment and clothing used for radiological work shall not be stored with personal street clothing.
4. Cleaned Personal Protective Equipment, such as face shields and respirators, that comes into contact with the wearer's face and Fermilab-issued non-personal protective clothing shall be surveyed after use in Contamination, High Contamination, or Airborne Radioactivity Areas. Contamination levels should be below Table 2-2 total contamination values prior to reuse. The use of statistically representative sampling is acceptable.

Radioactive Materials**Chapter 4**

5. Use of any type of protective clothing other than the disposable type must be approved by appropriately designated radiological control personnel.

462 Decontamination

1. Radiological Work Permits or technical work documents shall include provisions, as appropriate, to control contamination at the source to minimize the amount of decontamination needed.
2. Work planning shall include appropriate consideration of the handling, temporary storage and decontamination of materials, tools and equipment. More detail concerning work involving contaminated materials or areas can be found in Chapter 3.
3. Decontamination activities shall be controlled to prevent the spread of contamination or damage to the environment.
4. Water and/or steam are the preferred decontamination agents. Other cleaning agents should be selected based upon their effectiveness, hazardous properties, amount of waste generated and ease of disposal.
5. Decontamination methods should be used to reduce the number of contaminated areas.
6. Reasonable efforts should be made to reduce the level of contamination and the number and size of contaminated areas that cannot be eliminated.

463 Vacuum Cleaners and Portable Air-Handling Equipment

Improper use of vacuum cleaners and portable air-handling equipment may result in the generation of airborne radioactivity or loose surface contamination areas.

1. Vacuum cleaners and portable air-handling equipment used in Contamination, High Contamination, Airborne Radioactivity, and areas where radioactive material is used or stored (where the potential for contamination exists) shall be equipped with High-Efficiency Particulate Air (HEPA) filters. If the material to be vacuumed is wet enough to preclude resuspension, then HEPA filters are not necessary.
2. HEPA filters used in vacuum cleaner and portable air-handling equipment shall meet the efficiency and construction requirements for HEPA filters in MIL-F-51068. The maximum flow rate for the device shall not exceed the flow rate at which the HEPA filter was efficiency tested. In addition, the device shall be leak tested by the ES&H Section prior to initial use, when units have been opened, and annually. Leak tests are conducted by injecting DOP or equivalent aerosols

Radioactive Materials**Chapter 4**

- into the inlet of the device and measuring the DOP concentrations at the inlet and outlet of the device.
3. Vacuum cleaners used for radiological work shall be:
 - a. Uniquely marked and labeled
 - b. Controlled to prevent unauthorized use
 - c. Designed to ensure HEPA filter integrity under conditions of use
 - d. Designed to prevent unauthorized or accidental access to the inner surfaces of the vacuum.
 4. Radiation and contamination surveys shall be performed periodically for vacuum cleaners used in areas where the potential for significant contamination (exceeding values in Table 2-2) or measurable dose rate ($= 0.5 \text{ mR/hr.}$) exist. The frequency of radiation surveys should depend on the specific use of the vacuum cleaner.
 5. Airborne radioactivity levels should be monitored when a vacuum cleaner is used in High Contamination Areas or Airborne Radioactivity Areas.